Projecting Grammatical Features in Nominals: Cognitive Processing Theory & Computational Implementation

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ABSTRACT: *The cognitive processing theory and computational implementation of a linguistic theory of the representation and projection of grammatical features in nominals is described. The processing of nominals is part of a larger model of language comprehension implemented in the ACT-R cognitive architecture. The model combines a serial, pseudo-deterministic processing mechanism for building linguistic representations—implemented within ACT-R's production system—with a parallel, activation and selection mechanism for choosing between alternatives—implemented as an interaction between ACT-R's procedural (production) and declarative memory (DM) systems.*

1. Introduction

This paper describes an extension to a model of human language comprehension which incorporates grammatical features within nominals to support the binding of pronouns, anaphors and elliptical arguments, and to facilitate reference resolution. The language comprehension model has been under development in the ACT-R cognitive architecture (Anderson, 2007) since 2002 (Ball, 2003; Ball, 2007b; Ball, Heiberg & Silber, 2007) and is capable of handling a broad range of grammatical constructions. A key commitment is development of a model which is at once functional and cognitively plausible. We believe that adherence to well-established cognitive constraints may actually facilitate the development of a functional model by pushing development in directions that are more likely to be successful. Although there may be short-term costs associated with adherence to cognitive constraints, we expect, and have already realized, longer-term benefits (Ball et al., submitted). The dual commitment to functionality and plausibility distinguishes this research from most research in computational linguistics and computational psycholinguistics.

The language comprehension model is a key component of a larger synthetic teammate model (Ball, et. al, 2009) which includes language generation, dialog management and task behavior components, in addition to language comprehension. These components interface to each other through a situation representation component. The major components of the synthetic teammate are all being developed within ACT-R. The main objective of the synthetic teammate project is to develop cognitive agents capable of being integrated into team training simulations without detriment in training. To achieve this goal, the cognitive agents must be capable of closely matching human behavior across a range of cognitive capacities.

2. Linguistic Theory

The underlying linguistic theory is an adaptation of X-Bar Theory (Chomsky, 1970; Jackendoff, 1977) called Bi-Polar Theory (Ball, 2007a). In Bi-Polar Theory, there are four primary phrase internal grammatical functions: *head*, *specifier*, *complement*, and *modifier*. With respect to nominals or noun phrases (NPs), the typical head is a noun like "pilot" and the typical specifier is a determiner like "the" as in "the pilot". We reject the functional head hypothesis (Abney, 1987) which treats "the" as the head and "pilot" as a complement, aligning instead with Culicover & Jackendoff's (2005) "Simpler Syntax". The specifier and head—the most basic elements of a nominal—constitute the two poles of Bi-Polar Theory. At a minimum, a nominal will contain a specifier, a head, or both. The typical modifier—which is not required—is either an adjective like "old" which occurs between the specifier and head as in "the old pilot" or a prepositional phrase like "in the airplane" which occurs after the head as in "the pilot in the airplane". There are few true complements in nominals and they will not be considered in this paper. We prefer the terms nominal or object referring expression to NP, since the head of a nominal is not necessarily a noun—the head may be empty (e.g. "the red" in "I like the red" in reference to a red object) or it may contain a word or phrase that is not a noun (e.g. "running" in "the running of the bull" or "giving to the poor" in "his giving to the poor is nice").

It is a key claim of this research that words and phrases functioning as specifiers and modifiers—in addition to

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14. ABSTRACT
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heads—may project grammatical features to encompassing nominals. Grammatical features may be redundantly encoded in words and phrases fulfilling different grammatical functions. At the level of the nominal, the projected grammatical features are collected into a set without duplicates. Redundantly encoded grammatical features may occasionally conflict or a grammatical feature may be unspecified—without the expression being ungrammatical—necessitating mechanisms for handling conflicts and accommodating unspecified features.

The primary grammatical features include definiteness, number, animacy, gender, person and case. The definiteness feature is most closely associated with determiners like "the" and "a", demonstrative pronouns like "this" and "that" and quantifiers like "all" and "some". There are (at least) four possible values: *universal* (e.g. "all" in "all books"), *definite* (e.g. "the" in "the book"), *indefinite* (e.g. "a" in "a book"), and *negative* or *zero* (e.g. "no" in "no books"). The number, animacy and gender features are most closely associated with nouns. The possible values for number are *singular*, *mass* (a subtype of *singular*) and *plural*. The possible values for animacy are *human* (a subtype of *animate*), *animate* and *inanimate*. The possible values for gender are *male* and *female*. There is no *neuter* gender in English. With a few exceptions, only human (or animate) nouns are encoded for gender. Plural and mass nouns, but not singular count nouns, are also *indefinite*. For example, the singular count noun "man" is *singular*, *human* and *male*; the plural count noun "rocks" is *indefinite*, *plural* and *inanimate*; and the singular mass noun "rice" is *indefinite*, *singular* and *inanimate*. The grammatical features person and case are only associated with a small number of personal, possessive and reflexive pronouns (e.g., "I" is *first* person, *subjective* case; "me" is *first* person, *objective* case; "he" is *third* person *subjective* case; "him" is *third* person, *objective* case). All reflexive pronouns are objective case (e.g. "myself" is *first* person *objective*, "himself" is *third* person, *objective*) and all possessive pronouns are genitive case (e.g. "my" is *first* person, *genitive*, "hers" is *third* person, *genitive*). There are actually two genitive forms in English, one which functions as a specifier (e.g. "my" in "my book") and one which functions like a pronoun (e.g. "mine"). Although we use the term "case" to describe the genitive, it differs from subjective and objective case in important respects, especially in its specifier function.

To be grammatical, a nominal normally requires an indication of definiteness, typically provided by the specifier, and an indication of number, typically provided by the head. For example, in "the book", "the" is *definite* and "book" is *singular*. Since pronouns, proper nouns, and plural and mass nouns also provide an indication of definiteness, they can occur alone as nominals (e.g. "he" is *definite* and *singular*, "John" is *definite* and *singular*, "books" is *indefinite* and *plural* as in "books are fun to read"). On the other hand, singular count nouns do not provide an indication of definiteness and do not normally occur alone in nominals (e.g. "*book is fun to read").

A key aspect of language comprehension is determining the referents of nominals. The set of grammatical features projected to the nominal provides the grammatical basis for determining the referent, and is especially important for determining co-reference. For example, given the input "The man kicked the ball. She ran to first base." the nominal "the man" indicates that an object of type man is being referred to that is somehow salient in the context of the utterance. This salience is indicated by the *definite* feature of "the". Likewise for "the ball". On the other hand the occurrence of "she" is problematic. Pronouns normally indicate co-reference to a previously introduced referent. However, the *female* gender of "she" is inconsistent with the *male* gender of "the man" and the *human* animacy of "she" is inconsistent with the *inanimate* feature of "the ball". There is no previously mentioned referent to which the pronoun can co-refer.

Besides their importance for reference determination, grammatical features facilitate language comprehension in other ways. For example, interpreting the classic "flying planes are dangerous" vs. "flying planes is dangerous" depends on number agreement between the subject "flying planes" and the auxiliary verb "is" vs "are" with "flying planes" being ambiguous between a reading in which the head "planes" projects the feature *plural*, and a reading in which the head "flying" leads to construal of the expression as *singular*. Likewise, determining the meaning of "the book I gave the man" and "the man I gave the book" hinges on the animacy of "book" and "man", interacting with the ditransitive verb "give" which prefers an animate indirect object and an inanimate direct object.

Although grammatical features can be extremely useful for language comprehension, they are only useful to the extent that there is grammatical evidence that they exist. It makes little sense to treat common nouns as having case or person features since there is no grammatical marking for these features in English. For example, "the man" can occur as the subject or object as in "the man kicked the ball" and "the horse kicked the man". Including a case feature for common nouns simply introduces an ambiguity that must be resolved by the context in which the noun occurs—the noun itself provides no such indication. With respect to person, all common nouns could be treated as *third* person by analogy with *third* person pronouns which are grammatically distinct, coupled with claims that subject-verb agreement in English is based on both number and person. However, Ball (submitted) argues that subject-verb agreement in English is based strictly on number, with the exception of the *first* person pronoun "I" and present tense

verbs (e.g. "I am hungry"), making a *third* person feature for common nouns grammatically unnecessary.

We adhere to the basic principle that **where there is no grammatical distinction, there is no grammatical feature**. Without grammatical evidence, there is simply no basis for learners of English to learn the feature. Although most pronouns are marked for case and person in English, common nouns are not. Insisting that all nouns have case and person features to capture a (universal) generalization over nouns and pronouns, is counter-productive—the grammatical generalization introduces unnecessary ambiguity which does not facilitate comprehension. Knowledge of language involves representations or constructions at multiple levels of abstraction, with the most specific constructions that match a given linguistic input carrying most of the weight for language comprehension.

3. Psycholinguistic Theory

There is extensive psycholinguistic evidence that human language processing is essentially incremental and interactive (Gibson & Pearlmutter, 1998; Altmann, 1998; Tanenhaus et al., 1995; Altmann & Steedman, 1988). Garden-path effects, although infrequent, strongly suggest that processing is essentially serial at the level of phrasal and clausal analysis (Bever, 1970). Lower level processes of word recognition suggest parallel, activation-based processing mechanisms (McClelland & Rumelhart, 1981; Paap et al., 1982). At the level of phrasal and clausal analysis, humans appear to deterministically pursue a single analysis which is only occasionally disrupted, requiring reanalysis. One of the great challenges of psycholinguistic research is to explain how humans can process language effortlessly and accurately given the complexity and ambiguity that is attested (Crocker, 2005). As Boden (2006, p. 407) notes, deterministic processing "would explain the introspective ease and speed of speech understanding", but a purely deterministic, incremental processing mechanism would more frequently make incorrect local choices requiring reanalysis than is evident in human language processing. Marcus (1980) proposed a lookahead mechanism to improve the performance of a deterministic, yet monotonic, processor, bringing it into closer alignment with human performance. However, there is considerable evidence that humans immediately determine the meaning of linguistic inputs (cf. Tanenhaus et al., 1995; Altmann & Mirkovic, 2009) which is inconsistent with extensive lookahead, delay or underspecification—the primary serial and monotonic mechanisms for dealing with ambiguity. As Altmann & Mirkovic (2009, p. 605) note "The view we are left with is a comprehension system that is „maximally incremental"; it develops the fullest interpretation of a sentence fragment at each moment of the fragment"s unfolding". Not only is there not extensive lookahead, delay or underspecification, the human language processor engages in "thinkahead", predicting what will come next rather than waiting until the succeeding input is available before deciding on the current input.

To capture the essentially incremental nature of human language processing, we adopt a *serial*, *pseudo-deterministic* processor that builds linguistic representations by integrating compatible elements, relying on a non-monotonic mechanism of *context accommodation* to handle cases where some incompatibility that complicates integration manifests itself. Context accommodation makes use of the full context to make modest adjustments to the evolving representation or to construe the current input in a way that allows for its integration into the representation. Context accommodation need not be computationally expensive (i.e., a single production may effect the accommodation, just as a single production may effect integration without accommodation). In this respect, context accommodation is not a reanalysis mechanism that disrupts normal processing; rather, it is part and parcel of normal processing. Reanalysis mechanisms need only kick in when context accommodation fails and larger adjustment is needed. Further, as will be shown below, context accommodation can give the appearance of parallel processing in a serial processing mechanism, blurring the distinction between serial and parallel processing.

The mechanism of context accommodation is most closely related to the *limited repair parsing* of Lewis (1998). Context accommodation may be viewed as a very modest form of repair. According to Lewis (1998, p. 262) "The putative theoretical advantage of repair parsers depends in large part on finding simple candidate repair operations". The mechanism of context accommodation provides evidence for this theoretical advantage.

To capture the essentially interactive nature of human language processing, we propose a probabilistic, context-sensitive mechanism for activating alternatives in parallel and selecting the most highly activated alternative. This *parallel*, *probabilistic* mechanism selects between competing alternatives, but does not build any structure—building structure is the function of the incremental integration mechanism. At each choice point, the parallel, probabilistic mechanism uses all available information to activate and select the preferred alternative, and the serial, pseudo-deterministic mechanism integrates the preferred alternative into the evolving representation. Use of the full local context supports selection of alternatives that are likely to be correct, allowing the serial integration mechanism to be largely deterministic. However, the local context is not always consistent with the global context and locally preferred choices sometimes turn out to be globally dispreferred. The mechanism of context accommodation allows the processor to adjust the evolving representation to accommodate the subsequent context, without lookahead,

backtracking or reanalysis. Only when the context accommodation mechanism breaks down do more disruptive reanalysis processes become necessary. The use of the term *pseudo-deterministic* to describe the basic processing mechanism reflects the integration of parallel, probabilistic activation and selection mechanisms and context accommodation with what is otherwise a serial, deterministic processor.

4. Cognitive Processing Theory

ACT-R (Adaptive Control of Thought—Rational) is a computational implementation of a general cognitive architecture developed to model a broad range of cognitive capacities (Anderson, 2007). It consists of a production system combined with a declarative memory system and includes modest perceptual-motor capabilities for interacting with a computer. There is no distinct language subsystem within ACT-R (nor does the language comprehension model introduce such a subsystem). In ACT-R, a single production executes at a time, providing a serial bottleneck for processing, however, which production is selected for execution is determined by a parallel, utility selection mechanism. Similarly, declarative memory (DM) retrieval returns a single DM chunk, but selection of the chunk relies on a parallel, spreading activation mechanism. ACT-R is thus a hybrid serial, parallel architecture.

The language comprehension model—called Double-R (for Referential and Relational)—builds linguistic representations of referential and relational meaning based on the linguistic input, surrounding context and prior knowledge. The model uses ACT-R‟s production system to build representations, combined with ACT-R‟s declarative memory (DM) system to select grammatical constructions which are used to build these representations. Grammatical constructions (including word level constructions) are stored in DM and retrieved on the basis of spreading activation from the linguistic input and the prior context. The spreading activation mechanism interacts with the production system via a retrieval production which specifies the type of construction to be retrieved and the current goal. The single grammatical construction which matches the retrieval template and is most consistent with the linguistic input, prior context and current goal is retrieved. Separate integration and/or build productions determine how to integrate the retrieved construction into the evolving representation, either via integration into an existing representation or projection of a novel representation.

At the processing of each word in a linguistic input, humans typically succeed in identifying the word, determining the correct grammatical function of the word, and integrating the word into the evolving linguistic representation. The likely way this is accomplished is by using all available information—be it lexical, syntactic, semantic or pragmatic—to make the correct grammatical choice. This implies a highly context sensitive, parallel determination of the grammatical function of the current word (consistent with constraint-based theories), followed by the serial and deterministic integration into (or projection of) the evolving representation (an aspect of processing ignored—or at least de-emphasized—by most constraint-based theories). At each choice point, all information is considered in parallel in making the best choice, but once a choice is made, processing proceeds serially and deterministically forward until the next choice point.

In the processing of nominals, this means that the processing of each word leads to recognition of the word, determination of the appropriate phrase internal grammatical function of the word, projection of a higher level phrasal unit or integration of the grammatical function into an existing higher level phrasal unit, and projection of grammatical features from the grammatical function to the higher level unit. For example, in the processing of “the man”, the processing of the word “the” leads to recognition of the determiner “the”, determination of its grammatical function as a specifier, projection of a nominal construction, and projection of the grammatical feature *definite* to the nominal construction. The subsequent processing of “man” leads to recognition of the noun “man”, determination of its grammatical function as a head, integration of the head into the nominal construction projected by “the” and projection of the grammatical features *singular* (number), *human* (animacy) and *male* (gender) to the nominal construction. It is important to note that the determiner “the” projects a nominal construction. Not only do determiners project grammatical features, but they project nominal constructions and determine the category of the construction (functioning like a head in this respect). On the other hand, in the absence of a determiner (and projected nominal) a *plural* or *mass* noun can also project a nominal construction. For example, in “*rice* is good for you”, the mass noun “rice” projects a head which in turns projects a nominal construction (in the absence of a nominal construction projected by a determiner), and projects the grammatical features *indefinite* (definiteness), *singular* (number), and *inanimate* (animacy) to the nominal.

When the projection of grammatical features results in a conflict, blocking or overriding mechanisms—specific instances of context accommodation—come into play. The blocking and overriding mechanisms occur within the current context, making full use of the context to determine the appropriate projection of grammatical features. As an example of feature blocking, consider the nominal “the books”. The *definite* feature of “the” projects to the nominal and blocks projection of the *indefinite* feature of “books”. As an example of feature overriding consider the nominal “that dog”. The *inanimate* feature of “that” is overridden by the *animate* feature of “dog”. Grammatical evidence that “that” carries the feature *inanimate* is provided by expressions like

"I like that" in which "that" cannot normally be used to refer to an *animate* object.

Determination of the grammatical function of a word has important representational and processing implications. For example, in the processing of "that" in "that man", if "that" functions as a specifier and projects a nominal, then when "man" is processed, "man" can simply be integrated as the head of the nominal. In this case, "that" behaves like a typical determiner. However, if "that" functions as the head—behaving instead like a typical pronoun, then when "man" is processed, "man" must be accommodated by shifting "that" into the specifier function to allow "man" to function as the head. Whether or not "that" is encoded in the mental lexicon as a determiner, a pronoun (including relative pronoun), or both, is likely to depend on the history of use of the word. Regardless of which form is retrieved, the language processor must be capable of accommodating the alternative use. Given that the function of "that" cannot be fully determined until the subsequent input is processed (assuming an incremental processor without lookahead), retrieval mechanisms are likely to retrieve the most frequent form (unless the prior context is somehow able to bias retrieval of the alternative form). This basic fact is often overlooked in grammatical treatments which ignore processing considerations. Thus, it is often suggested that "that" in "that man" is a (demonstrative) determiner, whereas, "that" in "that is nice" is a (demonstrative) pronoun. For this to be the case, determining the part of speech of "that" would need to be delayed until after the subsequent input is processed, or ignoring processing, given the syntactic context surrounding "that".

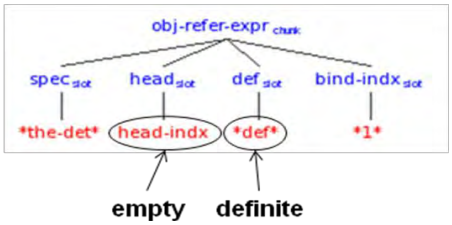
A similar mechanism is needed in the incremental processing of noun-noun combinations. For example, in the processing of "the altitude restrictions", when "altitude" is processed it can be integrated as the head of the nominal projected by "the", but when "restrictions" is subsequently processed, "altitude" must be shifted into a modifier function to allow "restrictions" to function as the head.

5. Computational Implementation

The language comprehension model contains a capability to display the representations that are generated from the linguistic input in a tree format (Heiberg, Harris & Ball, 2007). In the model, nominals are called object referring expressions (abbreviated "obj-refer-expr"). The use of the term "object **referring expression**" indicates that the representations are linguistic, but not purely syntactic, and highlights the importance of the referential dimension of meaning. The terminal nodes may contain words, but do not contain anything like abstract concepts or word senses. To more fully represent the meaning of the object referring expression, it must be mapped to a non-linguistic representation of the object to which it refers (within the situation representation). This mapping will not be discussed in this paper, but it is noted that the mapping is facilitated by the nature of the linguistic representations as compared to typical syntactic representations.

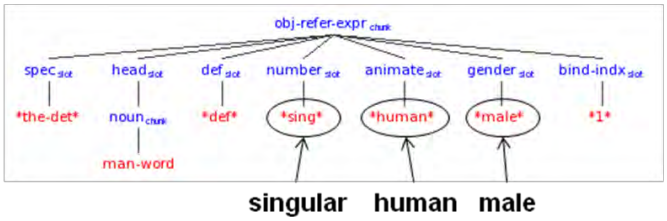
The processing of the nominal "the man" is shown below:

"the" →



The word "the" is identified as a determiner (abbreviated "*the-det*") that projects an object referring expression with "the" functioning as the specifier (abbreviated "spec"). The object referring expression chunk has a head slot. The value "head-indx" indicates that this slot does not yet have a value. The object referring expression chunk has a definiteness slot (abbreviated "def") which has the value *definite* (abbreviated "*def*"). This value was projected from "the". Finally, the object referring expression has a "bind-indx" slot which contains the index "*1*". This index supports the binding of pronouns, traces and anaphors in more complex linguistic expressions. It should be noted that the tree representations are simplified in various respects. In particular, the grammatical feature slots of the individual lexical items are not displayed. Further, only some slots without values are displayed. For example, the head slot is displayed even if it doesn't have a value, but grammatical feature slots and modifier slots (pre and post-head) without values are not displayed.

"the man" →



The processing of the word "man" leads to its identification as a noun and integration as the head of the object referring expression projected by "the". "Man" projects the grammatical features number, animate (i.e., animacy), and gender with the values *singular*, *human*, and *male* to the object referring expression.

The processing of pronouns like "his" and "her" introduces interesting challenges for an incremental processor. Consider the processing of "his book" (diagrams on page 7). The possessive pronoun/determiner "his"—treated as a possessive pronoun (abbreviated "poss-pron") by the model—projects a possessive object specifier (abbreviated "poss-obj-spec") which is a special type of object referring

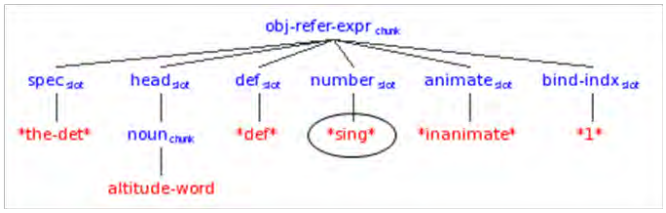
expression that functions as a specifier. In addition to the grammatical features typical of nouns and determiners, the features person and case with the values *third* and *genitive* (abbreviated "*gen*") are projected to the possessive object specifier. The possessive object specifier in turn projects a higher level object referring expression and functions as the specifier. The *definite* feature of the possessive object specifier is projected to the higher level object referring expression. Note that there are two distinct bind indexes to support co-reference to either object referring expression. The word "book" is recognized as a noun and integrated as the head of the higher level object referring expression projected by "his". The features *singular* and *inanimate* are projected to the higher level object referring expression. Overall, the object referring expression refers to an object of type book. Reference to this object is facilitated by inclusion of the possessive pronoun "his" which provides a *reference point* (cf. Taylor, 2000) for identifying the referent of the overall expression.

The pronoun "her" differs from "his" in that it is both a personal pronoun and a possessive determiner (e.g., "I like her" vs. "I like her book"). Whereas "her" alone functions as a personal pronoun, establishing a single referent, "his" alone does not. In "I like his", "his" is functioning as a possessive pronoun, not a personal pronoun. Possessive pronouns, unlike personal pronouns, establish dual referents via a separate reference point. Note that "his" unlike "her" is both a possessive determiner and possessive pronoun ("hers" is the possessive pronoun form of "her"). At the processing of the word "her", it is treated as a personal pronoun and functions as the head of the projected object referring expression, but if "her" is followed by "books", a higher level object referring expression is projected and "her" is shifted into a specifier function, so "books" can function as the higher level head (projection of the *indefinite* feature of "books" is blocked). As a personal pronoun, "her" also projects case and person features with the values *objective* (abbreviated *obj*) and *third*. From a processing perspective, the primary difference between "his" and "her" is that "his" immediately projects a higher level object referring expression and functions as a specifier within the higher level expression—setting up the expectation for a head—whereas "her" does not (see diagrams on next page).

The possessive pronoun "hers" differs from "his" in that there is no expectation for the occurrence of a head in the higher level object referring expression (i.e., "hers" cannot be a possessive determiner as in "*hers book"). This is indicated by marking the head of the higher level object referring expression as "*implied*" (a similar approach is adopted in the treatment of the implied subject of imperative statements) (see diagram on next page).

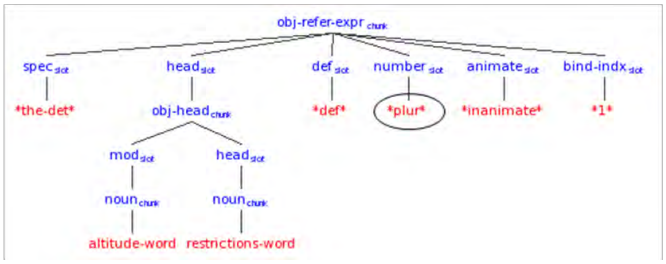
As a final example, consider the processing of "the altitude restrictions". The processing of "the" is as before.

"the altitude" →



The word "altitude" is identified as a noun and integrated as the head of the object referring expression projected by "the". "Altitude" also projects the grammatical features *singular* and *inanimate*. In parallel, "altitude" projects an object head structure with pre- and post-head modifier slots (see "obj-head" below showing pre-head "mod" and "head" slots). The capability of the model to build structures in parallel is extremely limited. In this case, the object head is projected in parallel but does not get integrated into a higher level structure unless needed to support subsequent processing. Integration of "altitude" (the noun) as the head is the minimum structure needed at this point in processing.

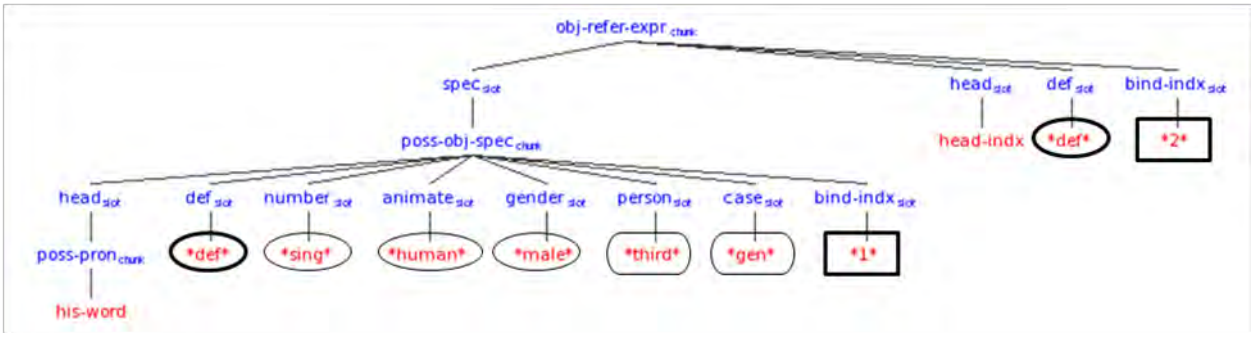
"the altitude restrictions" →



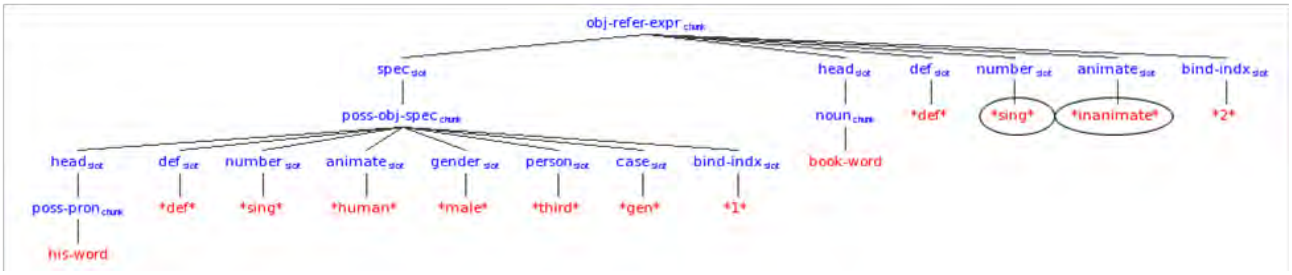
The word "restrictions" is identified as a noun. To accommodate "restrictions" the object head that was projected in parallel by "altitude" replaces "altitude" as the head of the object referring expression. In addition, "altitude" is shifted into the pre-head modifier slot of the object head (abbreviated "mod") to allow "restrictions" to function as the head. Finally, the *plural* number feature of "restrictions" overrides the *singular* number feature of "altitude". Note that at the end of processing it appears that "altitude" was treated as a modifier all along. The context accommodation mechanism gives the appearance of parallel processing without the computational expense of building and carrying forward multiple representations in parallel, although a limited amount of parallelism is supported. Context accommodation also minimizes the amount of structure building.

Whereas context accommodation can handle mundane examples like those discussed above, such examples differ from the disruptive garden-path examples which are typically used in psycholinguistic studies of reanalysis (e.g., the famous "the horse raced past the barn fell" from Bever, 1970). Context accommodation is not capable of handling such disruptive inputs.

"his" →



"his book" →



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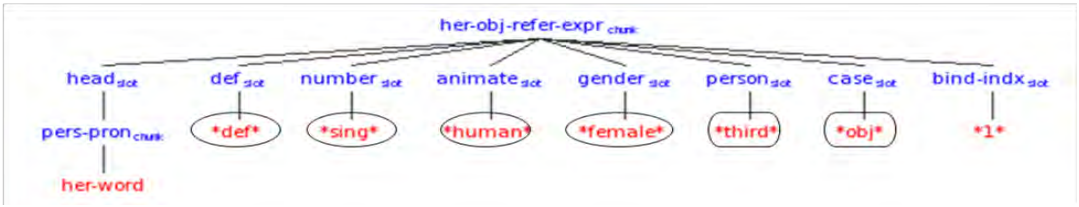

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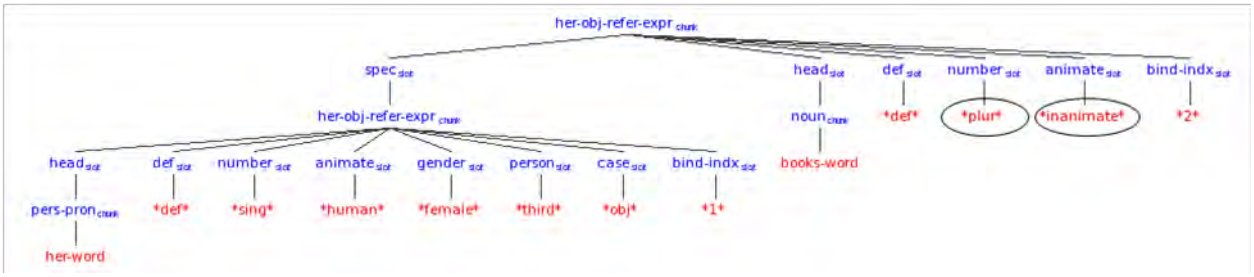

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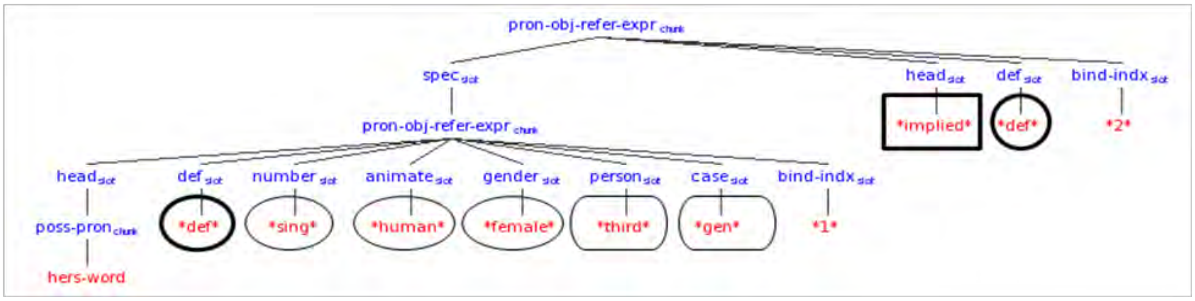

6. Summary

This paper has focused on describing aspects of the cognitive processing theory and computational implementation of grammatical feature processing in nominals within a larger model of language comprehension implemented in the ACT-R cognitive architecture. A serial, pseudo-deterministic processing mechanism grounded in ACT-R‟s production system, combines with a parallel, probabilistic mechanism grounded in an interaction between ACT-R‟s DM and production system. The pseudo-deterministic mechanism functions to build representations of the linguistic input, whereas the parallel, probabilistic mechanism functions to select between DM alternatives. A context accommodation mechanism for handling feature overriding and blocking supports modest adjustment of the evolving representation.

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